Mid-term report

Monitoring Greenhouse gas emissions from ditches in the Netherlands

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Introduction

Drainage of peatlands are a substantial source of greenhouse gasses (GHG) to the atmosphere (Bärbel et al., 2016; Hiraishi et al., 2014; Tiemeyer et al., 2016). The last decades many studies have focussed on quantifying the emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and related them to variables such as water table depth, soil organic carbon and (more recently) to the nitrogen content of the aerated soil (Bärbel et al., 2016). Considerably less attention has been paid to the emissions from the ditches draining the peat lands. Still, the emissions from these ditches can be substantial. A limited number of measurements in Dutch ditches, for instance, revealed an average diffusive CH_4 emission of 800 mg $CH_4/m^2/d$ (Schrier-Uijl et al., 2011). A simple extrapolation based on the 300.000 km ditch in the Netherlands (Higler, 1979) with a – very modest – estimated average width of 1m results in a total ditch emission of $2.4*10^5$ kg CH_4/d (~$8.2*10^6$ kg CO_2-eq/d). **Considering a yearly Dutch CH_4 emission of $19*10^9$ kg CO_2 eq/y (Coenen et al., 2017) suggests that ditches are responsible for 16% of the total Dutch CH_4 emission.** The estimation of ditch emissions as well as its contribution to the national emission should be interpreted with care. Ditch emissions, for one, are highly variable in space and time, and so far we have limited data on a few ditches from which only diffusive emissions were measured and the measurements were only conducted once, during summer. Omission of ebullitive CH_4 emission may lead to a considerable underestimation of total fluxes (e.g. Bastviken et al., 2008) whereas summer emissions tend to be highest (e.g. Yvon-Durocher et al., 2010) resulting in an overestimation of year-round fluxes. Secondly, due to a lack of data several CH_4 sources, including ditches, are not included in the national CH_4 emission estimate (Coenen et al., 2017).

This lack of data combined with the potential importance of ditch GHG emissions was the motivation to measure emissions from a set of 10 ditches on four different farms.

Objective

To quantify year-round GHG (CO_2, CH_4 and N_2O) emissions from ditches in the Netherlands and to identify easy-to-measure proxies enabling to upscale local measurements.

Methods

Study site

Ten ditches with different characteristics regarding width, depth, connection to underwater drainage pipes and connectivity to other ditches were selected to obtain insight in the variability in greenhouse

gas emissions (Table 1). The ditches were located in the North of the country at four farms. The ditches drain agricultural grasslands on soils that vary in the degree in which they (still) contain peat. The peat layer varied from being less than 1m thick to 2m at the different locations.

Table 1. Ditch characteristics

Location of the farm (N, E)	Ditch ID	Water Depth (cm) summer/winter	Sediment Depth (cm)	Width (m)
53°02'53.8"N 5°52'20.6"E	AWO	55/40	85	5.0
53°02'53.8"N 5°52'20.6"E	AWS	50/40	100	3.6
53°02'53.8"N 5°52'20.6"E	AWH	65/15	103	2.5
53°01'37.7"N 5°56'30.9"E	VNOD	50/35	46	3.8
53°01'37.7"N 5°56'30.9"E	VNS	35/20	75	2.0
52°56'36.2"N 5°40'16.2"E	KOD	50/40	78	2.8
52°56'36.2"N 5°40'16.2"E	KS	60/40	75	4.3
52°56'55.6"N 5°39'50.6"E	SOD	50/20	40	1.1
52°56'55.6"N 5°39'50.6"E	SS	45/3	60	1.8
52°56'55.6"N 5°39'50.6"E	SP	70/60	65	3.8

Field measurements

Field measurements were performed once every two to four weeks from May 2017 till June 2018 with the highest frequency in summer. This report contains the data up through January 2018 as the newer data still has to be analyzed (note that the figures in the appendix contain data through March). Each field visit diffusive fluxes of CO_2 and CH_4 were measured with a floating chamber (Fig. 1 and appendix 1) connected to an Ultra Portable Greenhouse Gas Analyzer (Los Gatos Research, CA, USA) or with a Picarro CRDS analyzer. When the Picarro was used also N_2O was measured. Diffusive flux measurements were conducted in triplicate. When sudden increases in CH_4 concentrations were observed (due to ebullition) the measurement was discarded and repeated.

In each ditch four bubble traps (Fig. 1 and appendix 1) were installed. Each field visit the volume of the collected gas was determined and a gas sample was taken to the lab to be analyzed for CH_4 concentration.

Figure 1: Floating chamber used to measure diffusive fluxes (left) and bubble traps used for ebullitive flux measurements (right). In ditches with low water levels (<30 cm) smaller bubble traps were used (smaller funnel and smaller bottle)

In addition the following water quality variables were analyzed in the ditch surface waters: CH_4, pH, dissolved oxygen, dissolved organic carbon (DOC), total inorganic carbon (TIC), ions (ICP-OES) and nutrients (auto-analyzer). On several occasions, sediment pore water samples were taken and analyzed for the same variables. Sediment samples for analysis of loss on ignition and C:N ratio were taken once in autumn.

A global warming potential of 34 for CH_4 and 298 for N_2O was used (100 year time frame, IPCC 2013).

Spatial and temporal variability in greenhouse gas emissions

The greenhouse gas emissions varied considerably in time (appendix 2). Although decomposition rates tend to increase strongly with temperature (e.g. Crowther et al., 2016; Davidson and Janssens, 2006) the variation in the emission of CO_2 and CH_4 – diffusive and ebullitive – are only significantly correlated to temperature in respectively 5, 2 and 3 of the ditches (Pearson correlation, 1-tailed). CO_2 emissions were negatively correlated with temperature and in several ditches CO_2 uptake occurred during warm months, indicating strong primary production by the ditch vegetation. CH_4 diffusion was correlated positively with the water temperature measured just above the sediment in one ditch and negatively in the other, pointing out that other processes than temperature enhanced methanogenesis are the main driver of ditch CH_4 emissions. **Hydrological circumstances – e.g. the water flow from the meadows to**

the ditches or inflow from other ditches– rather than temperature likely play a more important role in regulating greenhouse gas emissions from ditches. We will zoom in on this in future analyses.

Whereas inflow of dissolved gasses is a likely driver of diffusive fluxes in our ditches, the absence of a strong temperature effect on ebullition of methane (often observed in systems rich in organic matter (Aben et al., 2017; Maeck et al., 2014) may be due to overruling changes in hydrostatic or atmospheric pressure The volume of the captured gas, however, was significantly correlated with temperature in 9 or the 10 ditches. Possibly, higher temperatures favored the production of gasses other than CH_4 (e.g. N_2 due to nitrate reduction) or methane may have been lost from the bubble traps (due to diffusion into the water and/or oxidation) before the gas was sampled. The difference in CH_4 concentration in the bubble traps (the average concentration in the 10 ditches varied from 2 – 22%) and in gas bubbles collected after disturbing the sediment (collected once in summer, range 18-56%) substantiates the latter idea. Still, the differences in CH_4 concentration in bubbles "naturally" emerging and bubbles collected after the disturbance may also be due to the inclusion of deeper and younger bubbles when the sediment is disturbed. With the age of the bubbles nitrogen concentrations tend to increase and hence CH_4 concentrations tends to decrease (Walter et al., 2008). Hence disturbance may lead to an overestimate of the CH_4 concentration present in the ebullitive flux. We are currently working on estimating CH_4 loss from our bubble traps to quantify the potential losses. We expect that this will lead to an increase in our estimate of the ebullitive CH_4 flux.

The variation in flux intensities among the ditches could best be described by: loss on ignition in the case of ebullition (R^2=0.45; p=0.035) and pH in the case of diffusive CO_2 and CH_4 (negative correlation; R^2=0.76; p=0.001; R^2=0.74; p=0.001, respectively).

Relative contribution of different greenhouse gasses to the total emission

The relative contribution of CO_2 diffusion, CH_4 diffusion and CH_4 ebullition varies strongly among the ditches (fig. 2). This implies that emissions of both gasses and both pathways need to be included to estimate total greenhouse gas emissions. **In our 10 ditches the different fluxes were strongly correlated (fig. 3 and 4) suggesting that measurements of a single flux can be used to obtain a rough estimate of the other fluxes and thereby of the total flux.** Albeit hypertrophic, the relative contribution of CO_2 and CH_4 to the total greenhouse gas emission falls within the range of published papers on natural streams and rivers (fig. 5).

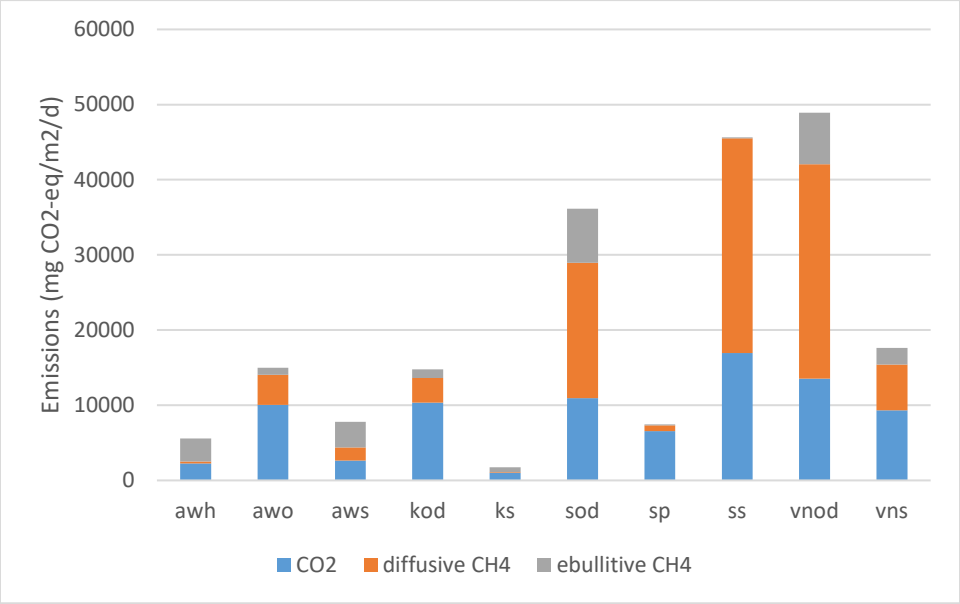

Figure 2: average CO_2, and CH_4 emissions between May 2017 - January 2018 from the 10 ditches

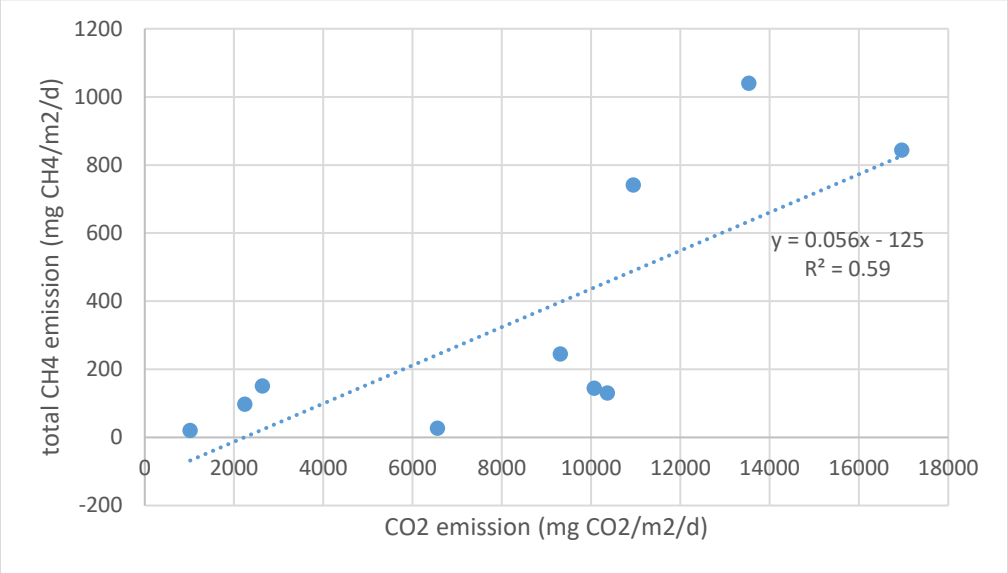

Figure 3: relationship between diffusive CO_2 emissions and total (diffusive + ebullitive) CH_4 emissions (data May 2017- January 2018)

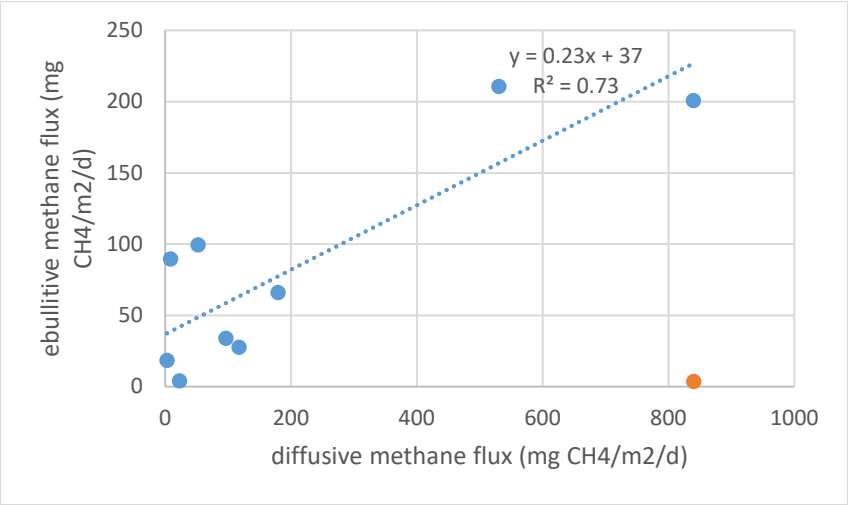

Figure 4: relationship between the diffusive and ebullitive methane flux, regression line excludes data from ditch 'SS' (red dot) where ebullition measurements were hampered by the low water table (data May 2017- January 2018)

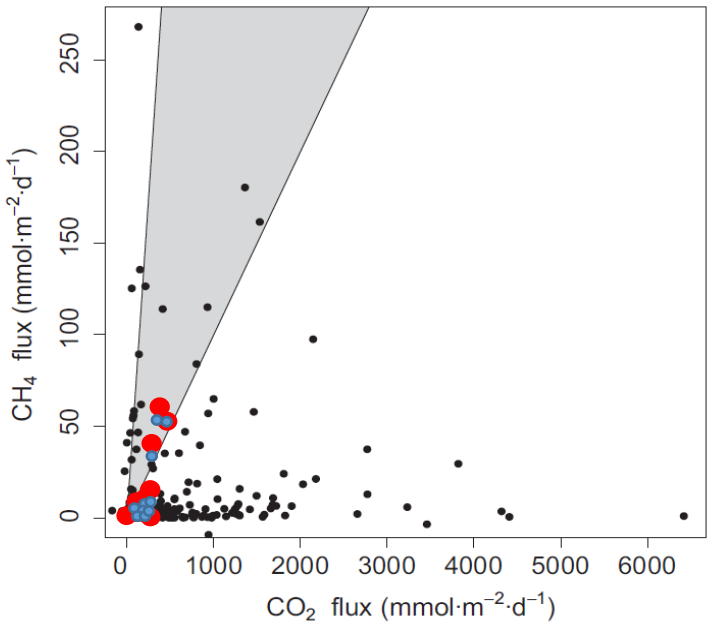

Figure 5: Comparison of CO_2 and CH_4 (red diffusive + ebullition; blue diffusive only) from the 10 Frisian ditches compared with diffusive emissions from streams and rivers with a wide geographic range (source: Stanley et al., 2016; the grey shaded area depicts a published data by Segers 1998)

N_2O emissions (measured from May till August) were generally low (~ 0.3 $mgN_2O/m^2/day$ equaling 89 mg CO_2-eq/m^2/d). The emissions were considerably higher after a rain event following a dry period (June 29). **The water flow from the re-wetted peat in the meadows to the ditch caused ditch N_2O emissions up to 97.6 $mgN_2O/m^2/day$ (~29085 mg CO_2-eq/m^2/d).** In the ditches N_2O emissions were 38.4 $mgN_2O/m^2/day$ (VNS) and 11.2 $mgN_2O/m^2/day$ (VNOD). The importance of N_2O for the total greenhouse gas emission from ditches clearly depends on the frequency of occurrence and the duration of these peak emissions. Further research is needed to shed light on this. Besides the timing and the amount of fertilizers used in the surrounding meadows, the hydrological connection between the meadows and the ditches is likely of importance for the N_2O emissions. High density drainage pipes possibly increase N_2O emissions when dry conditions are followed by precipitation through flushing out N_2O accumulated in the soil above the drainage pipes during dry conditions.

Importance of ditch emissions on a landscape scale

Greenhouse gas emissions from drained peatlands increase with drainage depth. Published data on Dutch peat indicate that the total emissions are 450 g CO_2-eq/m^2/y for each 10 cm of drainage below the soil surface (Fritz et al., 2017). When peatlands are drained to a depth of 50cm (which is still common practice in the Netherlands and potentially resulting in 2250 g CO_2/m^2/y land emissions) the average emissions of ditches (7324 g CO_2-eq/m^2/y) is more than 3 times higher than that of the terrestrial peat area on an areal (per m^2) basis. **When 20% of the landscape (or polder) area consists of ditches, these ditches are responsible for roughly 45% of the greenhouse gas emissions at the landscape scale.**

In the case of the polders studied here, however, CO_2 emissions from the grasslands seem substantially higher than those reported in literature (see preliminary data for 2017 in Van den Berg et al., 2018) and the surface area of the ditches (1.6-6.4%) is much smaller than in other parts of the Netherlands. Our preliminary data therefore suggests that in the Frisian polders ditches contribute less than 1% to the total greenhouse gas emission.

Next steps

- Extend database with data from January – June 2018
- Include precipitation and vegetation data in the analysis and further attempt to unravel drivers/predictors of greenhouse gas emissions from ditches
- Estimate potential CH_4 loss from bubble traps and incorporate in estimate of ebullitive flux

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Appendix 1: pictures field measurements

Diffusive flux measurements with floating chamber and Los Gatos (left) and bubble traps for ebullitive flux measurements (right)

Appendix 2: temporal variation in greenhouse gas emissions

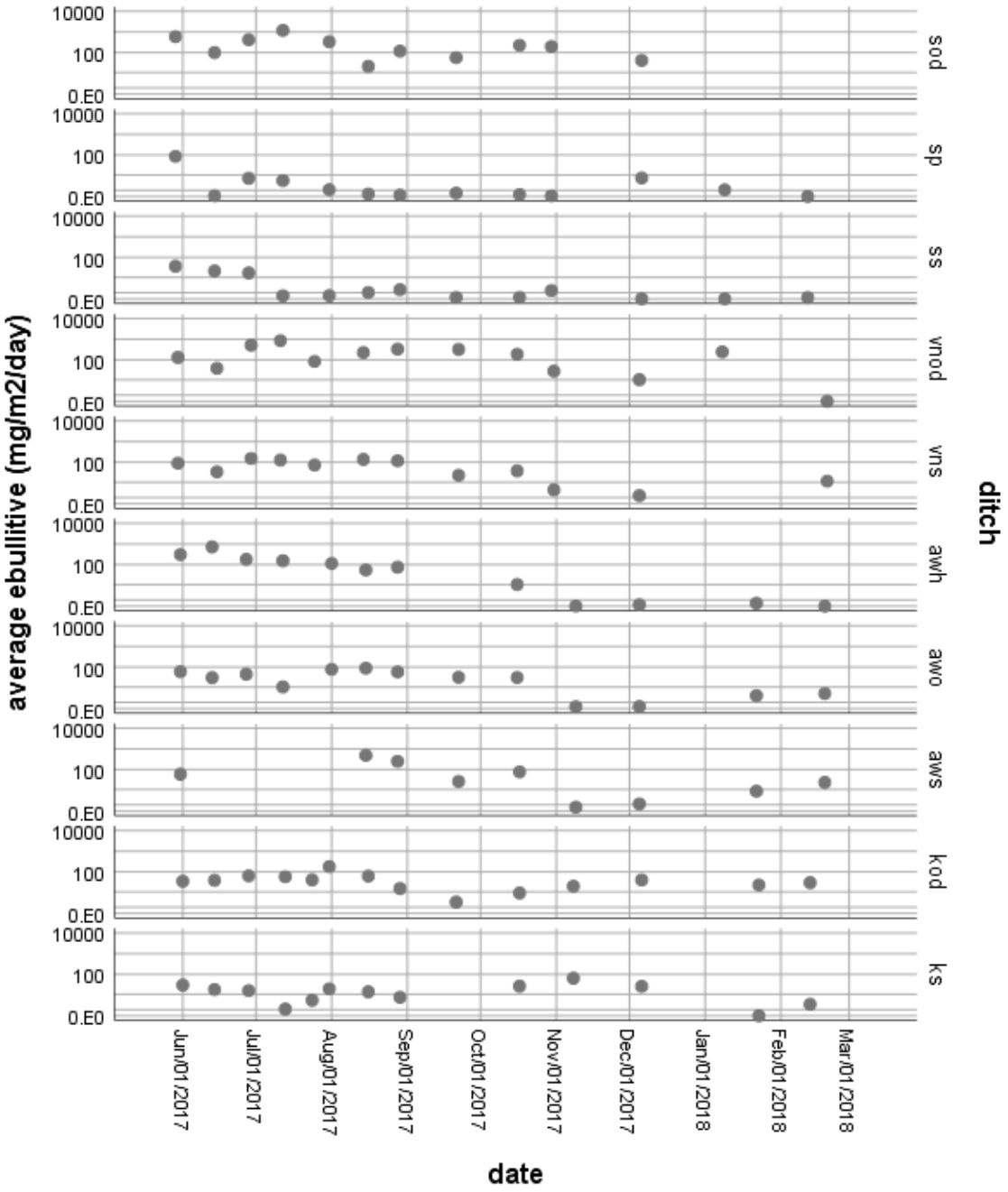

Figure A1: Ebullitive CH_4 emission in 10 ditches (mg $CH_4/m^2/d$)

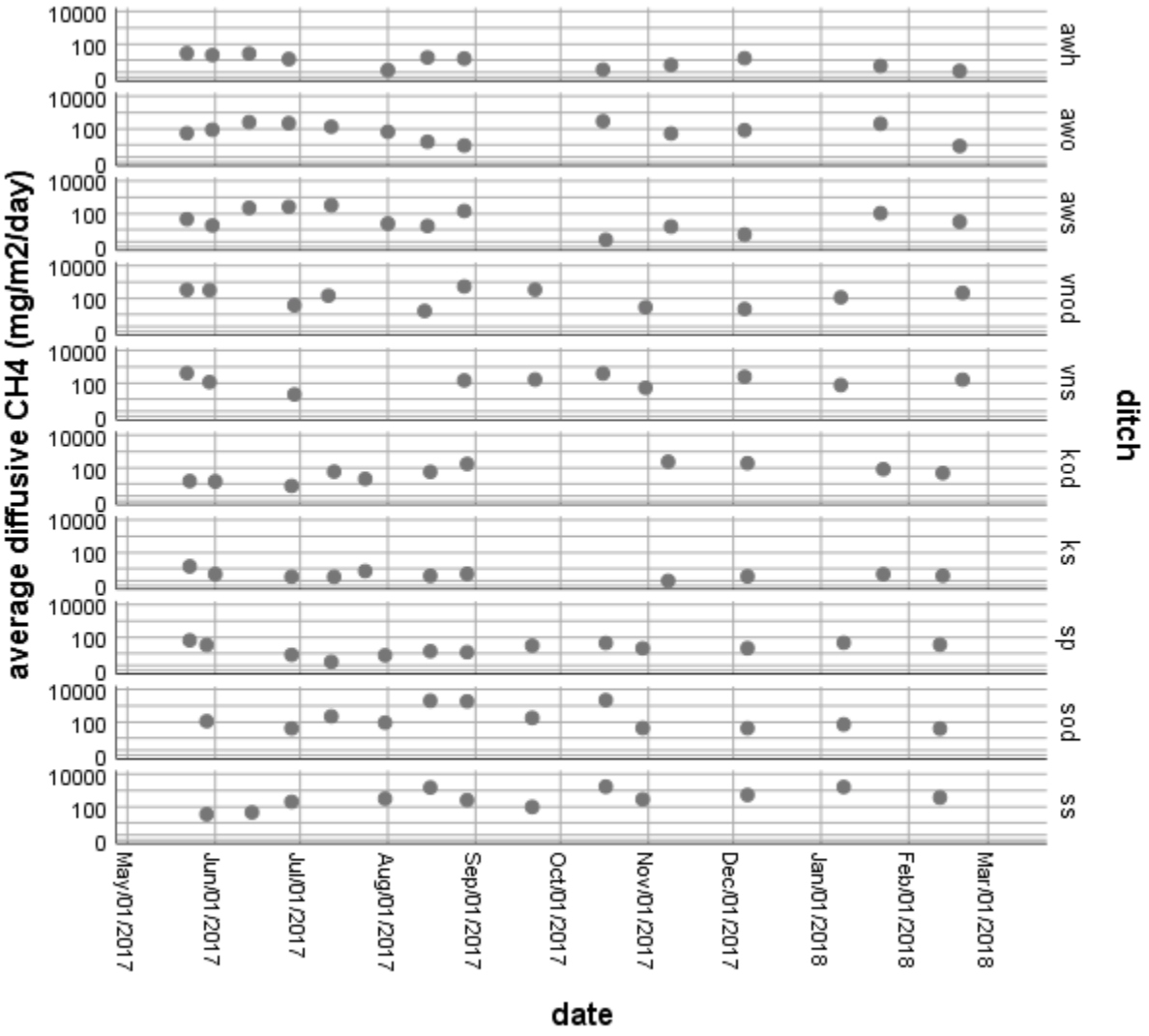

Figure A2: Diffusive CH_4 emission from 10 ditches (mg $CH_4/m^2/d$)

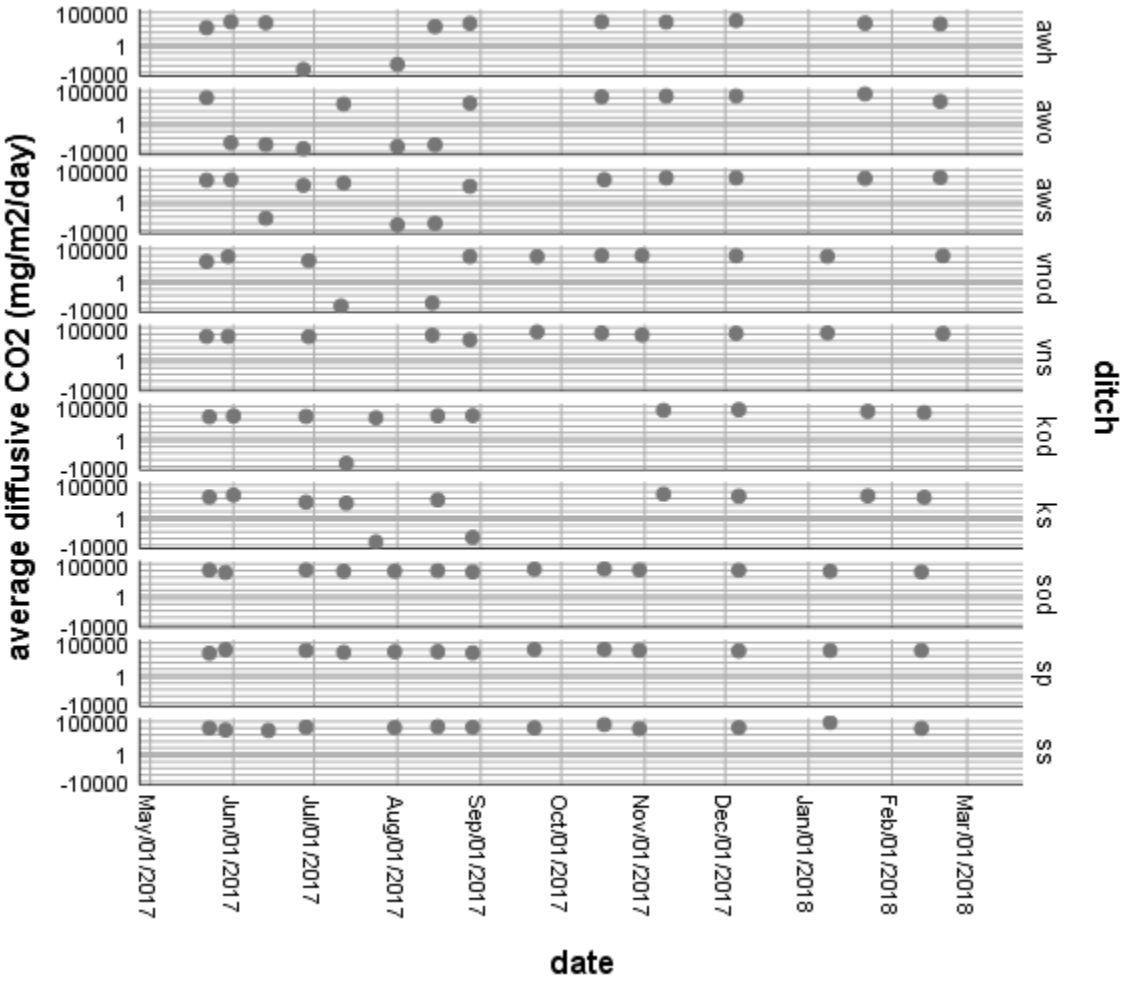

Figure A3: Diffusive CO_2 emission from 10 ditches (mg $CO_2/m^2/d$)